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COMMENTS ON CONGRESS INTERNATIONAL ASSOCIATION FOR  
HYDRAULIC RESEARCH (IA. (U) ARMY ENGINEER WATERWAYS  
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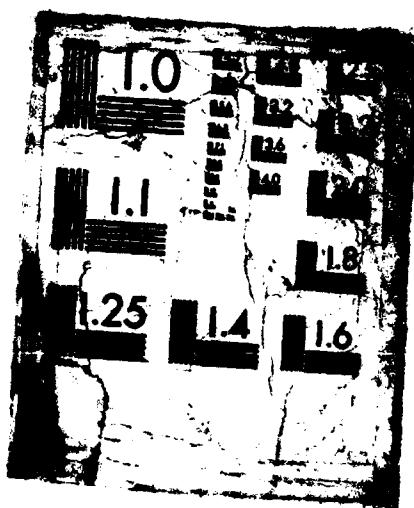
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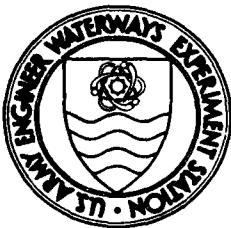
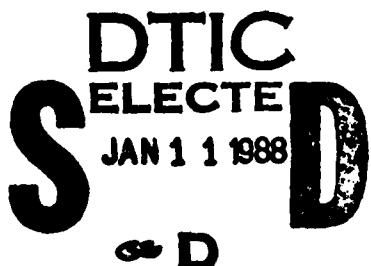
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COMMENTS ON TWENTY-FIRST CONGRESS  
INTERNATIONAL ASSOCIATION FOR HYDRAULIC  
RESEARCH (IAHR), MELBOURNE, AUSTRALIA  
19-23 AUGUST 1985

by

F. R. Brown

DEPARTMENT OF THE ARMY  
Waterways Experiment Station, Corps of Engineers  
PO Box 631, Vicksburg, Mississippi 39180-0631



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FIELD	GROUP	SUB-GROUP											
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Preface

This report summarizes the attendance of Mr. Fred Brown, former Technical Director of the US Army Engineer Waterways Experiment Station (WES), at the Twenty-First Congress of the International Association for Hydraulic Research (IAHR), Melbourne, Australia, 19-23 August 1985, under Invitational Travel Order I85-377, Appropriation No. 2152020, Operation and Maintenance, Army.

COL Dwayne G. Lee, CE, is the Commander and Director of WES.

Dr. Robert W. Whalin is the Technical Director.

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COMMENTS ON TWENTY-FIRST CONGRESS, INTERNATIONAL  
ASSOCIATION FOR HYDRAULIC RESEARCH (IAHR),  
MELBOURNE, AUSTRALIA, 19-23 AUGUST 1985

Introduction

1. In accordance with Invitational Travel Order I85-377 (Appendix A), I attended the Twenty-first Congress of the International Association for Hydraulic Research (IAHR) held in Melbourne, Australia, on 19-23 August 1985. I departed Los Angeles, California, on 16 August and traveled to Melbourne by way of Tahiti and Auckland, New Zealand, arriving on 18 August about 1250. I attended the entire meeting, 19-23 August, and participated in the Post-Congress Study Tour 1, which left Melbourne on 24 August. Travel included Alice Springs, Ayers Rock, and Sydney. I left Sydney, Australia, on 28 August for my return to the United States, touring New Zealand during the period 29 August-6 September and Tahiti during 6 September-13 September. I arrived in Los Angeles at 1735 on 13 September. All travel and stops other than for attendance at the Congress were at my personal expense. I was accompanied by my wife. Travel arrangements were made by American International Travel, Inc., of Vicksburg, Mississippi.

2. Simultaneously with the Congress, the International Measurement Confederation (IMEKO) held an International Conference on Flow Measurement (FLOMEKO). Registration permitted IAHR participants to attend sessions.

IAHR Congress

Arrangements

3. The hosts for the Twenty-first Congress were the Institution of Engineers, Australia, and the University of Melbourne. The City of Melbourne is known as the Garden City and is located in the State of Victoria, the southernmost and smallest state in Australia. It has a population of about 3 million. The University is Victoria's first, founded in 1853. It is situated on 19 hectares of land about 2 km north of the city. Total enrollment is about 16,000 students. Hotel accommodations were available within walking

distance of the campus and meeting rooms. Midday meals were available at the nearby local Union Building on campus.

4. Meeting rooms were adequate and fully equipped with audiovisual equipment. All presentations were in English with the exception of one series of papers when both French and English translations were provided. Six volumes of the preprinted proceedings were provided each participant upon registration. I mailed my copies back to the US Army Engineer Waterways Experiment Station (WES) for library accession and general use.

#### Attendance

5. The attendance was estimated to be about 400, which is down from previous Congresses. This can probably be attributed to the great travel distances for European and North and South American members. As to be expected, Australians and New Zealanders dominated the registrants. The United States was represented by 20 attendees, most of whom were from academic institutions. There was one representative from the Tennessee Valley Authority, one from the US Geological Survey, and three from WES (Mr. Steven C. Wilhelms, Dr. Todd L. Walton, Jr., and I). A list of registrants to 23 August and the organizations which they represented are shown in Appendix B. The US registrants are underlined.

#### Program

6. The overall Congress theme was "Hydraulic Research for Water Management in the Eighties." Actual subjects selected for discussion were:

- a. Subsurface Flow, Pollutant Transport, and Salinity.
- b. Free Surface Hydraulics and Water Management.
- c. Flows and Sediments in Harbors and Inlets.
- d. Flow Measurement and Data Acquisition.

Technical sessions were held from 0900 to 1730, Monday through Friday, with the number of sessions per day varying from three to six. The detailed technical program is included as Appendix C.

7. Four half-day seminars also were conducted during the Congress. These covered such subjects as urban drainage, hydraulic structures, hydraulic transients, and small hydropower generation.

8. The opening session on Monday was quite formal. In deference to possible disturbances, there was no general display of flags on the stage as in past Congresses. Following the Australian national anthem and remarks by E. J. Plate, President of IAHR, and Prof. Sir Douglas Wright, Chancellor of

the University of Melbourne, a presentation to the combined group was made by His Excellency, the Administrator of the Commonwealth of Australia, Sir James Rowland. The technical sessions were opened by the keynote speaker, Prof. G. Garbrecht, speaking on 5,000 years of hydraulic engineering. A copy of the opening program is attached as Appendix D. President Plate announced that T. Hayashi of Japan, H. Rouse of the United States, and M. Hug of France had been elected to Honorary Membership in the association.

9. Mr. Wilhelm's paper was given on Tuesday as part of Session 6. His paper, coauthored with Holland and Smith, and entitled "Advances in Selective Withdrawal Through a Point Sink," was well received. Dr. Walton's paper was presented on Thursday as part of Session 10. His paper was coauthored by Douglass and entitled "Stochastic Sand Transport Synthesis Using ARIMA Modeling." Generally all the papers in a session were reviewed by a General Reporter after which the author expanded on the remarks and answered questions. Many of the presentations by the General Reporters were difficult to follow because of the foreign accents. A novel timer used at each session involved the use of a float in a cylinder filled with water. An orifice in the base of the float caused it to sink in some predetermined time interval. It was effective in controlling the session lengths.

10. At the closing session the following members were elected to the Council to serve for the year 1986-87:

President	E. J. Plate, Germany
Vice Presidents	R. A. Elder, USA Y. Iwasa, Japan J. D. Lawson, Australia
Secretary/Treasurer	J. E. Prins, Netherlands
Members	J. P. Benque, France T. M. Dick, Canada J. J. Garcia, Venezuela R. J. Garde, India W. H. Graf, Switzerland V. Ya Karelina, USSR O. Starosolszky, Hungary

It was announced that the Twenty-second Congress would be held at Lausanne, Switzerland, from 31 August to 4 September 1987.

Comments

11. The Australian engineers made every effort to put on a good Congress. The technical programs were excellent as were most of the arrangements. The ladies' programs and outside tours also were appreciated by everyone. It was evident, however, that the group had little previous experience in fielding large international conferences. Minor unexpected problems frequently surfaced. Some of the participants had to change hotels because of advance reservation problems. At the closing banquet, one of the hotel pickup points was overlooked, and about 100 participants were stranded for about an hour; then the bus driver could not find the site of the banquet. However, one can judge it a successful Congress.

12. Attendance at the meeting permitted the renewal of old friendships and making of new ones, particularly with representatives from foreign laboratories. The opportunity to exchange ideas on common problems is considered invaluable. The technical program was the catalyst for such exchanges. Careful review of the proceedings should document the value of the technical papers and indicate possible new advances.

13. Australia is a young country with 90 percent of the 15 million population concentrated along the eastern seaboard. It is a land of extremes with lush garden spots and vast desert areas. The coastline is longer than that of the United States, and it has all the coastal problems experienced by this country. Water availability and water management are troublesome, particularly in the interior. Pollution and the environment are increasing problems. The Australian engineers are aware of the problems and are addressing them as resources permit. However, it is believed their technology is about 10 years behind the general state of the art as we know it in the United States. Hydraulic laboratory facilities are available for physical models at the University of Melbourne and at a site on the outskirts of Melbourne (Appendix E).

Post-Congress Technical Tour

14. I departed Melbourne on 24 August on one of the four post-Congress tours offered. I selected Tour 1, which was 6 days long. Travel to Alice Springs, Ayers Rock, and Sydney was by air. Ayers Rock is the world's largest monolith, located in the dry center of Australia about 400 km southwest of Alice Springs. It is one of the most isolated areas of the world with an

annual rainfall of 250 mm. The monolith measures about 3 km long, 2.5 km wide, and 335 m high. Aboriginal paintings and caves illustrate ancient tribal legends. Aborigine people also inhabit the general area of Uluru National Park in which it is located. On the park's boundary is a tourist resort, Yulara, which is a self-contained vacation area for visitors. A tour of the resort's power station desalination works (electrodialysis essential in the arid climate of the area), solar energy operations, and wastewater treatment works was made. Technical details were provided in handout material.

15. After 2 days at Ayers Rock, I returned to Alice Springs. This area, located in the geographical center of the continent, was opened in 1872 as a repeater station for the overland telegraph linking northern and southern Australia. In 1929 when it was joined to the south with a railroad, the population was only 200. Now its population totals about 40,000. The town's utilities and the Royal Flying Doctors Base headquarters were toured. My fellow participants in Tour 1 were Messrs. Iwasa, Ito, and Ogihara of Japan, Mr. Preston of New Zealand, Mr. McKenzie of Australia, Mr. Leutheusser of Canada, plus a guide from Sydney provided by the Congress. All were accompanied by their wives except for Messrs. Ogihara and McKenzie.

16. I arrived at Sydney on 27 August and left for Auckland, New Zealand, on 28 August. One never forgets Australia because of the \$22 departure tax.

#### New Zealand Tour

17. New Zealand consists of two large islands (North Island and South Island) and numerous small islands. It has a total population of 3 million people and 75 million sheep. Of the 3 million people, 800,000 are located in Auckland, which lies about 1,300 air miles east of Sydney. It is a mixed culture of English and Maoris and truly a sportsman's paradise.

18. My wife and I joined a tour by bus of the North Island on 29 and 30 August. We traveled through the town of Hamilton and dairy country to Waitomo and the glowworm caves. Then we went on to Rotorua and its boiling mud pools and geysers at the thermal reserve. Of interest was the use of geothermal areas as a source of energy. We also visited Arapuni Dam on the Waikato River. The dam is a concrete arch about 210 ft high. Power is generated by passing flow through 12-ft-diameter penstocks. A sheep shearing demonstration also was observed near Rotorua.

19. On 31 August we traveled to Queenstown by air and joined another bus tour of the South Island. We traveled through magnificent mountain scenery to Milford Sound where a launch cruise was made along the 10-mile waterway to the sea entrance. We were told the area had rain 340 days per year but we experienced only sunshine. We then continued on to the southern tip of the island at Bluff, back up the east coast to Dunedin, and on to Mount Cook. En route we inspected the hydroelectric development in the upper Waitaki and Mackenzie areas. A stop was made at the Benmore Dam. Descriptive material is attached as Appendix F. We arrived at Mount Cook on 4 September in the rain which later changed to snow. However, we left next day on schedule past Lake Pukaki and completed the tour at Christchurch on 5 September. We left Christchurch on 6 September for Auckland where we caught a New Zealand flight for Tahiti in French Polynesia that night. New Zealand Air was used for intercontinental travel because stops en route were permitted without an increase in fare.

#### Tahiti

20. Because of the international date line and time changes, we arrived in Papeete on 6 September and left the same day for the island of Huahine. These volcanic islands are part of the Society group and are located 3,700 miles from San Francisco and 2,400 miles south of Honolulu. Tahiti is the largest island and Papeete is the capital. Rugged mountains, blue water, white and black sand beaches, and unspoiled beauty have made Tahiti an ideal tourist retreat. The island of Huahine is located approximately 80 miles northwest of Tahiti and is a perfect place for those looking for seclusion and natural beauty. The Hotel Bali Hai is the only hotel on the island and offers thatched roof bungalows in a lush tropical setting. The beaches are of white sand but are not very large. The island has been open for tourism only for about 10 years. We left Huahine on 8 September for Bora Bora.

21. The trip to the Bora Bora Hotel consists of a 50-minute flight, a 40-minute boat ride to the village of Vaitape, and then a 6-mile bus ride. James Michener wrote that Bora Bora was the "most beautiful island in the world." We agree. The lush vegetation, hibiscus blossoms, sparkling white sand beaches, and crystal clear water of a large circular coral lagoon cannot be surpassed. Only 3,500 people live on the island and life is peaceful and slow. The absence of newspapers or TV cuts one off from the problems of the

world. We spent a restful 4 days before returning to the United States.

22. We left Bora Bora for Papeete on 12 September and boarded a plane for Los Angeles on 13 September, arriving there the same day. Thus ended an excellent educational and pleasure trip.

FRED R. BROWN



DEPARTMENT OF THE ARMY

U.S. Army Corps of Engineers  
WASHINGTON, D.C. 20314-1000

June 21, 1985

REPLY TO  
ATTENTION OF:

Office of Travel and Transportation

SUBJECT: Invitational Travel Order I85-377

Mr. Frederick R. Brown  
105 Stonewall Road  
Vicksburg, Mississippi 39180

Dear Mr. Brown:

You are invited to proceed from your place of business and/or residence in sufficient time to arrive in Melbourne, Australia, on or about August 18, 1985. The purpose of this mission is to permit you to obtain state-of-the-art knowledge in the field of hydraulics on Worldwide basis for application by the Corp. The period of this mission is approximately six (6) days. Upon completion of this mission, you will be reimbursed for expenses incurred in returning directly to point of origin.

Travel by rail, commercial or military aircraft, bus, and privately-owned-automobile is authorized. You are advised that the Department of Defense policy requires that in using regularly scheduled air transportation, accommodations selected will be the least costly service which will permit satisfactory accomplishment of the mission of the traveler.

If practicable, you will be provided a Government Transportation Request to exchange for carrier tickets. If transportation request is not used and travel is performed by common carrier at personal expense, reimbursement for the cost of transportation will be limited to:

- a. The least costly, regularly scheduled air service between the points involved, or the lowest cost class of accommodations available at the time reservations were made.
- b. The cost of the rail fare and lower berth, or the lowest first class rail accommodations available at the time reservations were made.
- c. Actual cost of commercial bus fare.

If you travel by privately-owned-automobile, reimbursement will be authorized at the rate of .20 $\frac{1}{2}$  cents per mile, plus the cost of necessary parking fees, bridge, ferry, and other highway tolls incurred while in a travel status

under this travel order. The total reimbursement will be limited to the cost of travel by the usual mode of common carrier including per diem. Receipts and ticket stubs will be required to substantiate your claim for cost of transportation and subsistence for items in excess of \$15.00.

Normally you will be entitled to a per diem allowance to cover your expenses for lodging, meals, and incidentals. While traveling and performing the mission within the continental United States, you will be authorized a per diem equal to the daily average amounts you pay for lodging, plus \$23 per day for meals and incidentals, rounded off to the next dollar. If the resulting amount is more than the maximum per diem allowable which is \$50, then only the maximum per diem will be authorized.

For the purpose of reimbursement, you are required to state on your reimbursement voucher that the per diem claimed is based on the average cost to you for lodging while on official travel within the continental United States during the period covered by the voucher. Receipts are required for lodging. The per diem allowance for travel overseas is based on rates established by the Department of State or by the Department of Defense. Accordingly, you will be authorized the amount specified for the particular overseas area involved.

Address any inquiries and submit voucher to U. S. Army Corps of Engineers, Waterways Experiment Station, P.O. Box 631, Vicksburg, Mississippi 39180-0631.

The travel herein has been determined to be in the public interest and is chargeable to: Appropriation No. 2152020, Operation and Maintenance, Army, WES Job Number QE5V020V117@001.

Sincerely,

*[Signature]* BOBBY C. HILL, Chief  
Logistics Management Division  
Office of Administrative Services

13/08/85

21ST IAHR CONGRESS

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21ST IAMR CONGRESS

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## THE CONGRESS PROGRAM - DETAILED SCHEDULE

**SUNDAY 18 AUGUST 1985**

1400-1900 Registration - Logic Classroom, Old Arts Building

**MONDAY 19 AUGUST 1985**

0800-0900 Registration - Logic Classroom, Old Arts Building

0900-1030 Plenary Session

Location: Wilson Hall

Opening ceremony

Opening: His Excellency AIR MARSHALL SIR JAMES ROWLAND, K.B.E., D.F.C., A.F.C., Administrator of the Government of the Commonwealth of Australia.

Keynote Address, Professor Dr.-Ing. G. GARBRECHT

"5000 years Hydraulic Engineering - 500 years Hydraulics - 50 years IAHR"

1030-1100 Morning Tea

1100-1230 Technical Session 1

Technical Session 1A - 1100-1230 Monday 19th August 1985

Sub-theme A.(a) - Modelling of recharge and sub-surface flows

Location: Public Lecture Theatre

Chairman: Dr. C. R. Dudgeon, University of New South Wales

Session Organizer: Mr. R. C. Lakey, Dept. of Minerals & Energy, Vic.

Presentation by General Reporter, Assoc. Prof. R.E. VOLKER, James Cook University, Qld.

Simultaneous translation provided

Papers (Proceedings Volume 1):

BONNETON, JARDIN, LAVEDAN & MOULLARD: "The MINOS Model Two-Dimensional Representation of Subsurface Flow in Saturated and Unsaturated Zones."

EDENHOFER & SCHMITZ: "Analytical Solution of the Infiltration Equation."

JAYAWARDENA: "Moisture Movement Through Unsaturated Porous Media: Numerical Modelling, Calibration and Application."

LIGGETT & DILLON: "A Dynamic Model of Flow Exchange Between Streams and Aquifers."

SCHMITZ, HAVERKAMP & PALACIOS: "A Coupled Surface-Subsurface Model for Shallow Water Flow Over Initially Dry Soil."

SEGURA & YEVJEVICH: "Stochastic Modelling of Groundwater Recharge."

STAUFFER & DRACOS: "An Advective Transport Model for Recharge Studies in Layered Soils."

TOWNLEY: "Response of Shallow Aquifer Systems to Periodic Recharge."

USSENKO: "Groundwater Flow Estimates for Artificial Groundwater Systems."

Technical Session 1B - 1100-1230 Monday 19th August 1985

Sub-theme B.(a) - Fundamental aspects of free surface flows

Location: Theatre B

**Chairman:** Prof. Ben Chie Yen, University of Illinois  
**Session Organizer:** Dr. I. O'Neill, University of Melbourne

**Presentation by Authors**

**Simultaneous translation not provided**

**Papers (Proceedings Volume 2):**

**VOLKART:** "Transition from Aerated Supercritical to Subcritical Flow and Associated De-aeration."

**ANISTIS & CHU:** "Entrapment Characteristics in a Recirculating Eddy"

**FUKUOKA & YAMASAKA:** "Equilibrium Wave Height and Flow on Alternate Bar Based on Non-Linear Relationships of Bedform, Flow and Sediment Discharge."

**KERESELIDZE & MUZAEV:** "Theoretical and Numerical Solutions of Some Problems Associated with Wave Motion in Rivers, Water-Pools and Reservoirs."

**FENTON:** "A Family of Stable Explicit Schemes for Computational Hydraulics."

**1230-1400** Lunch

**1400-1530** Technical Session 2

**Technical Session 2A – 1400-1530 Monday 19th August 1985**

**Sub-theme A.(a) Natural and artificial groundwater recharge**

**Location:** Theatre B

**Chairman:** Dr. T. Darcos, Federal Institute of Technology, Switzerland

**Co-chairman:** Dr. L. Townley, University of Western Australia

**Session Organizer:** Mr. J.G. Leonard, Dept. of Minerals and Energy, Vic.

**Presentation by Authors**

**Simultaneous translation not provided**

**Papers (Proceedings Volume 1):**

**AKAN & YEN:** "Groundwater Recharge From Overland Flow"

**PEREZ-FRANCO:** "The Nonlinear Approach of Groundwater Hydraulics as Applied to Artificial Recharge Through Wells."

**SHARMA, CRESSWELL & WATSON:** "Estimates of Natural Groundwater Recharge from the Depth Distribution of an Applied Tracer."

**VISWANATHAN:** "Estimation of Natural Recharge in an Unconfined Aquifer."

**WILLIAMS:** "Hydrogeology and Hydrochemistry of Natural and Induced Recharge of the Unconsolidated Sediments of the Lower Namoi Valley with References to the Effect of Artificial Recharge."

**Technical Session 2B 1400-1530 Monday 19th August 1985**

**Sub-theme B.(a) – Numerical computation of 2-D and 3-D flows**

**Location:** Public Lecture Theatre

**Chairman:** Dr. B. Westrich, University of Stuttgart

**Session Organizer:** Dr. I. O'Neill, University of Melbourne

**Presentation by General Reporter:** Dr D.R. BLACKMAN, Monash University

**Simultaneous translation provided**

**Papers (Proceedings Volume 2):**

**BENQUE, DALSECCO & ESPOSITO:** "Une Methode d'Elements Finis Pour le Calcul de Mareas et de Surcotes."

**CARBALLADA:** "Steady 2-D Linear and Non-Linear Model."

**GOPALAKRISHNAN, TUNG & WEI:** "A Numerical Model for Computing Storm Surge Flooding Extent."

KANOH: "Numerical Prediction for Two Dimensional Flow in Open Channels."  
McCOWAN: "Equation Systems for Modelling Dispersive Flow in Shallow Water."  
MISHUEV, SLADKEVICH & CHUMAKOV: "The Propagation of the Shock Wave in the Trapezoidal Channel."  
ROGOUNOVICH & SHNIPOV: "Calculation of Cross-flows in straight Rectangular and Trapezoidal Ducts with Variable Peripheral Roughness."  
SIEGERSTETTER, MICHEL & FRANKE: "Numerical Solution of Flow Around Objects — Are Super-computers the Answer?"  
TAMAI & IKEYA: "A Mathematical Model of a Three-Dimensional Flow Over Bars in Meandering Channels."  
WOLANSKI: "Numerical Modelling of Flow in a Tidal Creek — Mangrove Swamp System."

Seminar (b) Guidelines for the design of hydraulic structures — cavitation, dynamic forces, vibration

Location: Seminar Room

Session Organizers: Prof. A. Raudkivi, University of Auckland and Mr. K.A. Murley, Rural Water Commission

Lead Papers: R.E.A. ARNDT: "Cavitation"

E.J. LESLEIGHTER: "Flow-induced Vibrations"

J.B. HINWOOD & R.J. KELLER: "Hydrodynamic Forces"

The above are position papers on Monographs A4, A3 & A2 respectively for the IAHR Hydraulic Structures Design Manual.

Other papers by various authors available at the door.

Simultaneous translation not provided

1530-1600 Afternoon Tea

1600-1730 Technical Session 3

Technical Session 3A — 1600-1730 Monday 19th August 1985

Sub-theme A.(c) — Natural flows in regional-scale deep aquifers

Location: Theatre B

Chairman: Dr. C. Lawrence, Dept. of Minerals and Energy, Vic.

Session Organizer: Mr. C. Lakey, Dept. of Minerals and Energy, Vic.

Presentation by General Reporter, Mr S.J. HANCOCK, Australian Groundwater Consultants

Simultaneous translation not provided

Papers (Proceedings Volume 1):

AGBEDE & ARUMUGAM: "Mathematical Modelling of Deep Aquifers in Northern Nigeria."

BLACK & WOOLARD: "Measurement of Flows from the Mound Springs of the Great Artesian Basin."

DUDGEON: "The Validity of Darcy's Law in Low Shear-rate Flows in Aquifers."

KHADER & RAMADURGAIAH: "Flow Into a Well in Bounded Leaky Artesian Aquifers"

MICHIUE, SUZUKI & HINOKIDANI: "Unsteady Flow of Unconfined Groundwater in an Alluvial Plain."

SATO, YAMASAKI, KAMATA & FUJISAKI: "A Numerical Approach to Total Control System of Groundwater Resources in Saitama Basin."

van WONDEREN & DOTTRIDGE: "Simulation of Regional Groundwater"

**Flow Using Digital Models and Their Application to Planning of Ground-water Development."**  
**Technical Session 3B - 1600-1730 Monday 19th August 1985**  
**Sub-theme B.(a) - Numerical computation of 2-D and 3-D flows**  
**Location: Public Lecture Theatre**  
**Chairman: Dr. T. Tingsanchali, Asian Institute of Technology**  
**Session Organizer: Dr. A.H.F. Wong, Gutteridge, Haskins and Davey**  
**Presentation by General Reporter, Prof. Y. IWASA, Kyoto University**  
**Simultaneous translation provided**  
**Papers (Proceedings Volume 2):**  
CHAO-LIN CHIU & JYH-DONG CHIOU: "Flow-Shear Interaction in Rectangular Open Channels."  
CHENIN-MORDOJOVITCH & HAUGUEL: "The Internal Refined Grid in Particular Areas Inside a Two-Dimensional Mathematical Model."  
GVAZAVA, SHARIKADZE & OBGADZE: "Numerical Method of Solution of a Two-Dimensional Problem of Viscous Flow Around Solids Applied for Design of Fixing Members of Some Hydraulic Structures."  
KALKWIJK & KOPPEL: "Experiments on Unsteady Separating Flow in an Open Channel."  
MENDOZA & SHEN: "Steady Two-Dimensional Flow Over Dunes."  
NEZU & RODI: "Experimental Study on Secondary Currents in Open Channel Flow."  
PAVLOVIC & RODI: "Depth-Average Numerical Predictions of Velocity and Concentration Fields in Meandering Channels."  
PRZEDWOJSKI: "Bed Topography in Circular Bend."  
WIJBENGA: "Determination of Flow Patterns in Rivers with Curvilinear Coordinates."  
**Seminar (b) Guidelines for the design of hydraulic structures - cavitation, dynamic forces, vibration (continued).**  
**Location: Seminar Room**  
**Evening: State Reception (Delegates and accompanying persons.)**

**TUESDAY 20 AUGUST 1985**

0830-0900 Registration - Logic Classroom, Old Arts Building  
0900-1015 Plenary Session  
Location: Wilson Hall  
Keynote Address: Prof. I. R. WOOD, University of Canterbury:  
"Air Water Flows".  
Address by Recipient of the Ippen Award: Prof. K.G. Ranga Raju, University of Roorkee: "Transport of Sediment Mixtures."  
1015-1030 FLOMEKO '85 Opening Ceremony  
Location: Wilson Hall  
1030-1100 Morning Tea  
1100-1230 Technical Session 4  
**Technical Session 4A - 1100-1230 Tuesday 20th August 1985**  
**Sub-theme A.(d) - Groundwater movement in relation to land and water salination and soil consolidation**  
Location: Theatre B  
Chairman: Dr. M. L. Sharma, CSIRO  
Co-chairman: Dr. M.H. Abdul Khader, University of Singapore  
Session Organizer: Mr. J.G. Leonard, Dept. of Minerals and Energy, Vic.

**Presentation by Authors**

**Simultaneous translation not provided**

**Papers (Proceedings Volume 1):**

**BOOKER, SMALL & CARTER:** "Prediction of Subsidence Caused by Pumping of Groundwater."

**VOLKER & MARINO:** "Effects on the Salt Water Interface of Groundwater Pumping on Ocean Atolls."

**DAS GUPTA & DE MEL:** "Multi-Layer Solute Transport Model and Its Application."

**IFE & TREWHELLA:** "Estimates of the Groundwater Budget of an Irrigated Region near Shepparton, Australia."

**MYNAREK:** "Design Geotextiles as Protective Filters."

**Technical Session 4B – 1100-1230 Tuesday 20th August 1985**

**Sub-theme B.(c) – Transport and mixing in rivers and reservoirs**

**Location:** Lecture Theatre C

**Chairman:** Prof. N. Rajaratnam, University of Alberta

**Co-chairman:** Dipl.-Ing P. Hanscheid, RWTH, Aachen.

**Session Organizer:** Mr. W.T. Wong, Monash University

**Presentation by Authors**

**Simultaneous translation not provided**

**Papers (Proceedings Volume 2):**

**ABDEL-GAWAD & MCCORQUODALE:** "Initial Mixing of Cross Flowing Jets in Trapezoidal Channels."

**GERARD, PUTZ & SMITH:** "Mixing Downstream of a Small Bank Outfall in a Large Northern Stream."

**JOHNSTON:** "Aspects of Buoyant and Non-buoyant Jets Entering Shallow Tailwaters."

**D'ANDREA & BADDOUR:** "The Turbulent Domain of an Unconfined Surface Thermal Plume."

**TIPLER:** "The Controlled Discharge of Chemically Treated Meatworks Effluent to the Waimakariri River."

**Technical Session 4D jointly with FLOMEKO '85 – 1100-1230 Tuesday 20th August 1985**

**Sub-theme D.(d) – Laboratory measurement and instrumentation Location:**

**Public Lecture Theatre Chairman:** Dr. E.A. Spencer, IMEKO

**Co-chairman:** Dr. B.B. Sharp, University of Melbourne

**Session Organizer:** Dr. H.R. Graze, University of Melbourne

**Presentation by General Reporter, Prof. F. DURST, University of Erlangen**

**Simultaneous translation provided**

**Papers (Proceedings Volume 5):**

**BARCZEWSKI:** "Development of a Laser-Fluorometer for Sensitive, Local Concentration Measurements in Flows."

**BROWAND & PLOCHER:** "Image Processing for Sediment Transport."

**GULLIVER:** "Open Channel Flow Measurements in a Moving-Bed Flume."

**HAENSCHEID, KIRSCHBAUER & ROUVE:** "Image Processing – A Modern Flow Measurement Technique."

**LEGONO & RAO:** "Velocity Distribution Across the Width of a Rectangular Open Channel as Revealed by the Laser Doppler Anemometer."

**MUELLER:** "A Three Component LDA Tested in the Mixing Layer Behind Dunes."

**ODGAARD:** "Measurements of Secondary Currents in Curved, Movable-

**Bed Channel."**

**OESCH, BURRY & SCHNEITER:** "Leves Topographiques Par Moire Sur Modeles A Fonds Mobiles."

**PLATE, MAIER-ERBACHER & FREIDRICH:** "The Effects of a Wall on Turbulent Flow. A Comparison of Laboratory Experiments with Wind and Water Flow over Rough Boundaries."

**VASILCHENKO:** "Velocity Measurements at Rough Water-Permeable Flow Boundaries."

**1230-1400** Lunch

**1400-1530** Technical Session 5

**Technical Session 5A – 1400-1530 Tuesday 20th August 1985**

**Sub-theme A.(b) – Pollutant transport in aquifer flows**

**Location:** Public Lecture Theatre

**Chairman:** Mr. A.K. Turner, University of Melbourne

**Co-chairman:** Dr. A. Das Gupta, Asian Institute of Technology

**Session Organizer:** Mr. R.C. Lakey, Dept. of Minerals and Energy, Vic.

**Presentation by Authors**

**Simultaneous translation provided**

**Papers (Proceedings Volume 1):**

**ROWE & BOOKER:** "Pollutant Transport Through Clayey Soils and Underlying Aquifers."

**BRILLY:** "A Dual Porosity and Hydrodynamic Dispersion in the Direction of Flow in Porous Media."

**KOBUS & SPITZ:** "Transverse Mixing of Stratified Flows in Porous Media."

**BARBER & DAVIS:** "Groundwater Quality Monitoring: Representative Sampling from Boreholes to Determine Variations in Quality with Depth and Time."

**Technical Session 5B – 1400-1530 Tuesday 20th August 1985**

**Sub-theme B.(c) – Mixing processes in rivers and reservoirs**

**Location:** Theatre C

**Chairman:** Dr. B. Barczewski, University of Stuttgart

**Session Organizer:** Mr. A.D. McCowan, Lawson and Treloar Pty. Ltd.

**Presentation by General Reporter, Dr I.G. WALLIS, Consulting Environmental Engineers**

**Simultaneous translation not provided**

**Papers (Proceedings Volume 2):**

**ARNOLD, PASCHE & ROUVE:** "Mixing in Rivers with Compound Cross-Section."

**CHAPMAN:** "Time of Travel Studies in the Yarra River."

**IWASA & AYA:** "Lagrangian Characteristics of Longitudinal Mixing in Free Surface Shear Flows."

**LAWRENCE:** "Mixing in Steady Two-layer Flow Over Topography."

**MAXWORTHY & MONISMITH:** "Differential Deepening of a Mixed Layer in a Stratified Fluid."

**NOKES:** "Dispersion of Buoyant Particles in Two-Dimensional Turbulent Open Channel Flow."

**PHILIPS:** "Circulation and Mixing Characteristics in a Service Reservoir."

**PLATE, FRIEDRICH & DITTRICH:** "Wind and Flow Induced Mixing in Rivers and Reservoirs: The Effect On Reseration."

- TAUS:** "Mixing Processes in Lakes Following the Discharge of Sewage Water."  
**VUKELIC:** "Degree of Mixing of Pollutants in the Vardar River Through the Area of the City of Skopje as a Function of the Probability."  
**Technical Session 5D – 1400-1530 Tuesday 20th August 1985**  
**Sub-Theme D.(a) – Flow measuring techniques for rivers and lakes**  
**Location: Theatre B**  
Chairman: Dr. T. Milne Dick, National Water Research Institute, Canada  
Co-chairman: Dr. J.J. Peters, Ministry of Public Works, Belgium  
Session Organizer: Dr. H.R. Graze, University of Melbourne  
Presentation by Authors  
Simultaneous translation not provided  
**Papers (Proceedings Volume 5):**  
BILLFALK & DAHLBACK: "The Use of a Telemetric Computer-controlled System for Water Level Measurements."  
MUSZKALAY & STAROSOLSKY: "Two- and Three-Dimensional Flow Metering in Large Rivers."  
ASANO, YOSHINO & HAYAKAWA: "Improvement of Accuracy of Flow Measurement Technique in Alluvial Rivers."  
LAMMEL & VALENTIN: "Field Measurements in the Mixing Region Between River Inflow and Lake."  
FISHER: "Inexpensive Instrumentation for Measurement of Low Velocities in Shallow Lakes."  
**FLOMEKO '85 Session – 1400-1600 Tuesday 20th August 1985**  
General (including Turbine Flow)  
**Location: Theatre A**  
Chairman: Dr. F. C. Kinghorn  
Co-chairman: Dr. D. B. Prowse  
Presentation by Authors  
Simultaneous translation not provided  
**Papers:**  
MATTINGLEY: "Prospects for Improvements in Fluid Metering Via New Research Tools."  
SALAMI & HUTTON: "Development of a Turbine Flowmeter Calibration Rig."  
SIENICKI & BAKER: "Using Microcomputer Technology to Improve Flow Measurement Accuracy in the Petroleum Industry."  
JELFFS & HAYWARD: "Developments in the Accurate Metering of Natural Gas Liquids."  
**1530-1600 Afternoon Tea**  
Poster Paper Session (Authors present)  
**Location: Corridors, Old Arts Building**  
**1600-1730 Technical Session 6**  
**Technical Session 6A – 1600-1730 Tuesday 20th August 1985**  
**Sub-theme A.(b) – Pollutant transport in aquifer flows**  
**Location: Public Lecture Theatre**  
Chairman: Dr. R. Habermehl, Bureau of Mineral Resources, Australia  
Session Organizer: Mr. J.G. Leonard, Dept. of Minerals and Energy, Vic.  
Presentation by General Reporter, Assoc. Prof. K.K. WATSON, University of New South Wales

Simultaneous translation provided

Papers (Proceedings Volume 1):

AMER & BAZARAA: "Hydrothermal Impacts of Salt Gradient Solar Ponds on the Surrounding Soil. A Discrete Kernel Approach For Unlined Ponds."

MERKEL, SCHMITZ & HAVERKAMP: "Temperature Affected Pollutant Transport Phenomena in Unsaturated Soil."

MINKIN, KUTATELADZE, KAVTUASHVILI & BESELYA: "Transport Equations of Non-conservative Impurities and Their Solution for an Aquifer."

OLENIK, TELIMA & SIRIY: "Numerical Simulation of the Moisture and the Salts Motion While Studying the Transfer of the Contaminant Substances and Dissolution of the Soils."

PELKA & DORGARTEN: "Nonconservative Pollutant Transport in Saturated-Unsaturated Groundwater Flow."

SATO, SHIMIZU & ITO: "Applied Study On Pollutant and Heat Diffusion Around Underground Cavern."

Technical Session 6B - 1600-1730 Tuesday 20th August 1985

Sub-theme B.(c) – Stratified flows and selective withdrawal in rivers and reservoirs

Location: Theatre C

Chairman: Prof. E. Plate, University of Karlsruhe

Session Organizer: Mr. A. D. McCowan, Lawson and Treloar Pty. Ltd.

Presentation by General Reporter, Assoc. Prof. D. WILKINSON, University of New South Wales

Simultaneous translation not provided

Papers (Proceedings Volume 2):

DELVIGNE: "A Model for Vertical Diffusion in Stratified Shear Flows."

DENTON: "Density Current Inflows to Run of the River Reservoirs."

HIRATA & MURAOKA: "Internal Wave and Temperature Microstructure in Thermally Stratified Lakes."

IWASA & INOUE: "Mathematical Simulation of Plane and Multi-Layer Flows in a Large and Deep Lake."

KRANENBURG: "Laboratory Experiments on Mixed-layer Deepening in Water Bodies of Limited Extent."

MEARES: Hydrodynamic Aspects of the Treatment of Water in an Open Cut Using a NonMixing Cycle."

SPIGEL & OGILVIE: "Importance of Selective Withdrawal in Reservoirs With Short Residence Times: A Case Study."

WILHELM, HOLLAND & SMITH: "Advances in Selective Withdrawal Through a Point Sink."

FLOMEKO '85 Session – 1630-1830 Tuesday 20th August 1985

Electromagnetic and Vortex Flow

Location: Theatre A

Chairman: Dr. R. B. Mottram

Co-chairman: Mr. P. Sharpen

Presentation by Authors

Simultaneous translation not provided

Papers:

KINGHORN, MacLEAN, EBERLE & KALKHOF: "The Use of Electro-magnetic Flowmeters as Transfer Standards."

**JOHN & JOHNSON:** "Streamflow Measurement Reviewed with Emphasis on Two Lesser-Used Approaches."

**SOTNIKOV & MURZIN:** "Comparison Studies of Flowmeter Calibration Procedures Using Weighing Technique."

**LUCAS & TURNER:** "Influence of Cylinder Geometry on the Quality of Its Vortex Shedding Signal."

**BENTLEY:** "The Development of a Vortex Flowmeter for Gas Flows in Large Ducts."

**Evening:** Evening free

**WEDNESDAY 21 AUGUST 1985**

**0830-0900** Registration - Logic Classroom, Old Arts Building

**0900-1030** Technical Session 7

Technical Session 7B - 0900-1030 Wednesday 21st August 1985

Sub-theme B.(c) - Numerical modelling of transport and mixing in rivers and reservoirs

Location: Public Lecture Theatre

Chairman: Dr-Ing B. Berczewski, University of Stuttgart

Session Organizer: Prof. B.B. Willetts, University of Aberdeen

Presentation by General Reporter, Prof. W. RODI, University of Karlsruhe

Simultaneous translation provided

Papers (Proceedings Volume 2):

**BECHTELER & SCHRIMPFF:** "A Numerical Calculation for the Deposition of Fine Sediment in Horizontal Settling Basins."

**BELLEUDY & SAUVAGET:** "A New System for Modelling Pollutant Transport in River and Canal Networks."

**CZERNUSZENKO:** "Transport and Dispersion in Rivers."

**FORURIA, SIVAKUMAR & VOLKER:** "A Simulation Model for Management of Water Quality in a Water Supply Reservoir."

**HOLLY & TODA:** "Hybrid Numerical Schemes for Linear and Nonlinear Advection."

**JOKELA & PATTERSON:** "Quasi Two-Dimensional Modelling of Reservoir Inflow."

**KEILLER & CLOSE:** "Modelling Salt Transport in a Long River System".

**KUO & CHEN:** "Unsteady Hydraulic and Water Quality Modeling for a River-Estuarian System."

**MUROTA & MICHIOKU:** "Field Observation and Numerical Modelling of Thermal Structure in a Pumped Storage Reservoir."

Technical Session 7D jointly with FLOMEKO '85 - 0900-1030 Wednesday 21st August 1985

Sub-theme D.(c) - Laboratory measurement; unsteady flow measurement

Location: Theatre A

Chairman: Dr. B.A. Christensen, University of Florida

Co-chairman: Dr. B.B. Sharp, University of Melbourne

Session Organizer: Dr. H.R. Graze, University of Melbourne

Presentation by General Reporter, Prof. C. APELT, University of Queensland

Simultaneous translation not provided

Papers (Proceedings Volume 5):

**ABDEL-GAWAD, HANNOURA & McCORQUODALE:** "Rapidly Accelerated Flow Past Multiple Obstructions."

**BEGUIN & SCHNEITER:** "Automatic Measurement of Water Level."

**BRITTON, DRUERY & FLOYD:** "Flow Measurement and Data Acquisition  
Port Hacking, NSW, Australia."

**CASH:** "Practical Aspects of Computerised Real Time Automatic Control  
and Data Acquisition of a Large, Dynamic, Multi-Tributary Tidal Flood  
Plain Physical Model."

**ISAACSON:** "Laboratory Measurement and Generation of Multi-Direc-  
tional Surface Waves."

**JOHNSTON:** "Turbulent Shear Stress Measurement Using Hot-Film  
Anemometry."

**LEVIN & LOPATIN:** "Straightening of Velocity Profiles and Decrease of  
Turbulence Intensity by Confusers."

**MULLE & HOPWOOD:** "Video Tape Recording of Float Tracks and  
Velocities in Hydraulic Model Studies."

**OGIHARA:** "A Proposal on Extended Reynolds Number."

**RAO & HALL:** "An Experimental study of the Development of Turbulence  
in Open Channels."

**SALAMI:** "Problems in Prediction of Prototype Performance of Large  
Axial Flow Fans From Model Tests."

**Seminar (a) Urban drainage hydraulics**

**Location:** Seminar Room

**Seminar Organizers:** Prof. E.M. Laurenson, Assoc. Prof. R.G. Mein, Monash  
University

**Lead Papers (Proceedings Volume 6):**

T. MILNE DICK & J. MARSALEK: "Manhole Head Losses in Drainage  
Hydraulics."

M.J. BOYD: "Stage-Discharge Relations for Culverts and Outlets."

**Other Papers by various authors available at door**

**Simultaneous translation not provided**

**Morning tea**

**Technical Session 8**

**Technical Session 8B – 1100-1230 Wednesday 21st August 1985**

**Sub-theme B.(c) – Transport and mixing in rivers and reservoirs**

**Location:** Public Lecture Theatre

**Chairman:** Prof. H. Kobus, University of Stuttgart

**Co-chairman:** Dr-Ing B. Westrich, University of Stuttgart

**Session Organizer:** Prof. B.B. Willetts, University of Aberdeen

**Presentation by Authors**

**Simultaneous translation provided**

**Papers (Proceedings Volume 2):**

SHARP & HERAT: "Dynamic River Bend Flow Observations."

TSANIS & LEUTHEUSSER: "Experiments on Simulated Wind-Induced  
Water Currents."

PRASUHN & KNOFZYNSKI: "Improved Computation of Fall Velocity."

FONCK, GRILLI, LEJEUNE & SAHLOUL: "Open Channel Hydraulics and  
Water Management."

**Technical Session 8C – 1100-1230 Wednesday 21st August 1985**

**Sub-Theme C.(c) – Stability of tidal inlets and coastal structures, control of  
tidal flows**

**Location:** Public Lecture Theatre

**Chairman:** Mr. F. Biesset, Consultant, France

**Session Organizer:** Mr. D. L. Reid, Monash University

**Presentation by General Reporter, Mr B. DRUERY, Dept. of Public Works.**

**N.S.W.**

**Simultaneous translation provided**

**Papers (Proceedings Volume 4):**

**AKKERMANN, KONTER, HILLEN & PILARCZYK:** "Design Criteria for Rockfill Closures of Tidal Gaps."

**GIESECKE & HORLACHER:** "Measuring and Calculating Transient Pressure Fields Resulting from Wave Motion on a Submerged Cylindrical Tank."

**GRILLI & SAHLOUL:** "Wave Action on Coastal Structures."

**HEYER & HOLZ:** "A Mathematical Study of the Control of Morphodynamics in a Tidal River."

**LAMBERTI, PETRILLO & RANTERI:** "A Comparative Analysis of Some Types of Submerged Barriers as Beach Defence Structure."

**PILARCZYK:** "Stability of Revetments Under Wave and Current Attack."

**SCHOLTEN:** "The Rhine-Meuse Estuary Hydraulic Scale Model."

**SOBEY & JOHNSON:** "Wave Diffraction Through A Narrow Gap."

**WILLIAMS:** "Influence of Form on Tidal Response of Estuarine Lake Inlets in New South Wales."

**SELEZOV & ZHELEZNYAK:** "Scour of Sea Bottom in Front of Harbour Seawalls."

**Seminar (a) Urban drainage hydraulics (continued)**

**Location: Seminar Room**

**FLOMEKO '85 Session – 1100-1230 Wednesday 21st August 1985**

**Velocity Integration**

**Location: Theatre A**

**Chairman: Mr. J. Waldron**

**Co-chairman: Dr. G. Cignolo**

**Presentation by Authors**

**Simultaneous translation not provided**

**Papers:**

**CHRISTENSEN:** "Measurement of Flow, Bed Shear, and Roughness Characteristics in Open Channels by an Air Bubble Device."

**TAKEDA, R. & TAKEDA, F.:** "Accuracy of the Laser Doppler Velocimeter Systems."

**BETTOCCHI & CANTORE:** "Experimental Analysis of the Flow in a Conical Diffuser."

**1230-1330** **Lunch**

**1330-1730** **Technical Inspection:** Major pumping station, hydraulic structures on main sewer, and sewage treatment system, Werribee Farm.

**1330-1520**

**FLOMEKO '85 Session**

**Legal, Metrology, Density, etc.**

**Location: Theatre A**

**Chairman: Prof. P. H. Sydenham**

**Co-chairman: Mr. G. F. Hazzard**

**Presentation by Authors:**

**Simultaneous translation not provided**

**Papers:**

**HOERLEIN:** "The Application of Legal Metrology to Flow-Measuring Equipment in Australia."

**DIJSTELBERGEN:** "The Measurement of Compressed Natural Gas in Public Refuelling Stations."  
**PROWSE, LATIF & OWEN:** "Calibration of Vibrating Spool Densitometers for LPG Custody Transfer."  
**ASCHENBRENNER & WATANABE:** "Intercomparison of Gas Flow Test Facilities in the USA, Europe and Japan."

- 1540-1730** **FLOMEKO '85 Session**  
**Piston Provers**  
**Location:** Theatre A  
**Chairman:** Mr. K. Huntsman  
**Co-chairman:** Mr. G. F. Hazzard  
**Presentation by Authors**  
**Simultaneous translation not provided**  
**Papers (provisional list)**  
ALASIA & CIGNOLO: "Design Criteria for a 1200 Litre Capacity Piston Prover for Primary Gas Volume and Flowrate Measurements."  
BELLINGA, KOOI, HOEKS, van LAAK & ORBONS: "Using a Piston Prover as a Primary Standard in High Pressure Gas Metering."  
DIJSTELBERGEN, McKAY & STANNARD: "Commercially Available Gas Meter Provers - An Inter-Comparison of Their Performance."  
GROENEVELD: "Gravimetric Calibration of Volumes at the Division of Applied Physics."  
**Evening:** Barbecue and Social Function: Werribee

**THURSDAY 22 AUGUST 1985**

- 0830-0900** **Registration – Logic Classroom, Old Arts Building**
- 0900-1030** **Technical Session 9**  
**Technical Session 9B – 0900-1030 Thursday 22nd August 1985**  
**Sub-theme B.(b) – Interaction of main channel and flood plain flows**  
**Location:** Theatre B  
**Chairman:** Dr. R.J. Keller, Monash University  
**Session Organizer:** Mr. W. T. Wong, Monash University  
**Presentation by Authors**  
**Simultaneous translation not provided**  
**Papers (Proceedings Volume 3):**  
MCKEE, ELSAWY & McKEOGH: "A Study of the Hydraulic Characteristics of Open Channels with Flood-Plains."  
RADOJKOVIC & DJORDJEVIC: "Computation of Discharge Distribution in Compound Channels."  
ZHELEZNYAKOV: "Problem of Interaction of the Main Channel and the Floodplain Flows."  
NALLURI AND JUDY: "Interaction Between Main Channel and Flood Plain Flow."  
PASCHE, ROUVE & EVERS: "Flow in Compound Channels with Extreme Flood-Plain Roughness."  
**Technical Session 9D – 0900-1030 Thursday 22nd August 1985**  
**Sub-theme D.(b) – Measurement of aquifer and stormwater flows**  
**Location:** Public Lecture Theatre  
**Chairman:** Dr. A. Muller, Institute of Hydromechanics, Switzerland  
**Co-chairman:** Mr. S. Morgan, Melbourne & Metropolitan Board of Works  
**Session Organizer:** Dr. H.R. Graze, University of Melbourne

**Presentation by Authors**

**Simultaneous translation provided**

**Papers (Proceedings Volume 5):**

DUDGEON & KESHAVARZ: "Flow & Heat Transfer in a Heat-Pulse  
Borehole Flowmeter."

HJELMFELT, SPOMER & KRAMER: "Discharge Measurement Problems  
for Field Size Agricultural Catchments."

ZECH: "Mesure Du Débit Dans Les Egouts Pluviaux."

KLEINSCHROTH, KRUG, SIEGERSTETTER & FRANKE: "Measurements  
on Unsteady Two-Phase Flow in a Sewage Pipeline."

BOURAS & COMOLET: "Débitmétrie et Volumétrie par Effet Tourbillonnaire."

**FLOMEKO '85 Session – 0830-1030 Thursday 22nd August 1985**

**Nozzles (including Critical Flow)**

**Location: Theatre A**

**Chairman: Dr. D.B. Prowse**

**Co-chairman: Dr. G. Cignolo**

**Presentation by Authors**

**Simultaneous translation not provided**

**Papers:**

NARJES: "A New Method for the Direct Determination of a Venturi  
Nozzle's Discharge Coefficient at Transonic Flow."

SNELL: "A Simple Continuous Gas Mixing System Using Sonic Nozzles."

WRIGHT: "The Application of Sonic Nozzles to the Automated Accuracy  
Testing of Gas Flowmeters."

CAW, BRYANT & PROWSE: "The Comparison of Critical Flow Nozzles  
Using Networks Analogous to the Wheatstone Bridge."

CAW, BRYANT & PROWSE: "Pressure Divider Measurements to Define  
Reynold's Number Effects in Critical Flow Nozzles."

**1030-1100 Morning Tea**

**Poster Paper Session (Authors present)**

**Location: Corridors, Old Arts Building**

**1100-1230 Technical Session 10**

**Technical Session 10B – 1100-1230 Thursday 22nd August 1985**

**Sub-theme B.(b) – Flood flows in channels and flood plains**

**Location: Public Lecture Theatre**

**Chairman: Dr. A. Verwey, Inter. Inst. for Hydraulic & Env. Engg., Delft**

**Co-Chairman: Dr. E. Pasche, RWTH, Aachen**

**Session Organizer: Mr. W.T. Wong, Monash University**

**Presentation by General Reporter, Prof. J.A. CUNGE SOGREAH**

**Simultaneous translation provided**

**Papers (Proceedings Volume 3):**

APELT, LAWRENCE, WELLINGTON & YOUNG: "Mathematical Modelling  
of Channel - Flood Plain Exchange."

ATKINS & WALSH: "The Peaceful Co-Existence of Lae City and the  
Bumbu River in Papua New Guinea."

BOEV: "Phenomenons of Floods in Strumica Field and the Function of  
the Regulation of River Strumica."

DARTOUT, STEIN, LEPELLETIER & VASSILIADIS: "Effets des Barrages  
Ecrêteurs et des Aménagements de Vallées sur la Propagation des

**Crues du Bassin de la Seine en Amont de Paris mise au Point d'un  
Modele Mathematique de Simulation."**

**GABOS & YANG MINQUIN: "A Flood Plain Management Model In  
China."**

**KANDA: "Concurrence of Flood Flow and Invasion of Storm Surge in the  
Tidal River."**

**RAJAGOPALAN, BELGAL & HARDIKAR: "Consideration of Floodplain  
Storage for Narmada Design Hydrograph."**

**TINGSANCHALI: "Computation of Flow in Rivers and Flood Plains  
Under Different Backwater Effects and Data Constraints: Northeast  
Thailand."**

**VONGVISESSOMJAI, TINGSANCHALI & CHAIWAT: "Bangkok Flood  
Plain Model."**

**YEN, CAMACHO, KOHANE & WESTRICH: "Significance of Flood Plains  
in Backwater Computation."**

**Technical Session 10C – 1100-1230 Thursday 22nd August 1985**

**Sub-theme C.(b) – Numerical and field studies of sediment movement in  
coastal areas and estuaries**

**Location: Theatre C**

**Chairman: Assoc. Prof. R.J. Sobeck, University of California at Berkeley  
Co-chairman: Mr. B.M. Druery, Dept. of Public Works, N.S.W.**

**Session Organizer: Mr. D. L. Reid, Monash University**

**Presentation by Authors**

**Simultaneous translation not provided**

**Papers (Proceedings Volume 4):**

**JAIN & KENNEDY: "Sediment-Laden Circular Wall-Jet."**

**NIELSEN: "Oscillatory Boundary Layers: A Different Problem."**

**ISAACSON, M.: "Sediment Erosion Around Artificial Islands."**

**WALTON & DOUGLASS: "Stochastic Sand Transport Synthesis Using  
ARIMA Modeling."**

**FLOMEKO '85 Session – 1100-1230 Thursday 22nd August 1985**

**Ultrasonic Flowmeters**

**Location: Theatre A**

**Chairman: Mr. P. Sharpen**

**Co-chairman: Dr. B. B. Sharp**

**Presentation by Authors**

**Simultaneous translation not provided**

**Papers:**

**SANDERSON & TORLEY: "A Self-Calibrating Clamp-on Transit Time  
Ultrasonic Flowmeter."**

**WALUS: "The Use of the Ultrasonic Flowmeter in the Conditions Other  
Than Normal."**

**KARRAS, TORNBERG & HARKONEN: "The Ultrasonic Inferential Mass  
Flowmeter for Solids Carried by the Pulp Suspension"**

**ERICKSON & BISTRIAN: "Application of Ultrasonic Flowmeters to  
Hydro-electric Plant Flow Measurements."**

**1230-1400 Lunch**

**1400-1530 Technical Session 11**

**Technical Session 11B – 1400-1530 Thursday 22nd August 1985**

**Sub-theme B.(b) – Flood flows in channels and flood plains**

**Location:** Theatre B

**Chairman:** Prof. J.A. Cunge, SOGREAH

**Co-chairman:** Dr-ing E. Peache, RWTH, Aachen

**Session Organizer:** Dr. M.J. Keller, Monash University

**Presentation by General Reporter:** Dr. A. VERWEY, International Inst. for Hydraulic and Env. Engg., Delft.

**Simultaneous translation not provided**

**Papers (Proceedings Volume 3):**

ALAVIAN & CHU: "Turbulent Exchange Flow in Shallow Compound Channels."

CHEE & RAY: "Conveyance of Channels with Overbank Flow."

CHIN-LIEN YEN: " Routing by Diffusion Method in Channels with Floodplains."

CHRISTENSEN: "Open Channel and Sheet Flow over Flexible Roughness."

KLAASSEN & van URK: "Resistance to Flow of Flood Plains with Grasses and Hedges."

OGINK: "On The Effective Viscosity Coefficient in 2-D Depth-Averaged Flow Models."

REED: "An Example of the Effect of Depth-Sensitive Values of Manning's n on Nonuniform Flow Computations."

ROBERTS, PERNIK & BENKE: "Mixing in River-Floodplain Systems."

WONG: "Reach Sub-Division for Storage Flood Routing in Rivers."

**Technical Session 11C – 1400-1530 Thursday 22nd August 1985**

**Sub-theme C.(b) – Fundamentals of sediment movement in coastal areas and estuaries**

**Location:** Public Lecture Theatre

**Chairman:** Dr. J. Ploeg, National Research Council, Canada

**Co-chairman:** Dr. M. de StQ. Isaacson, University of British Columbia

**Session Organizer:** Mr. D. L. Reid, Monash University

**Presentation by General Reporter:** Dr H.P. RIEDEL, Riedel and Byrne

**Simultaneous translation provided**

**Papers (Proceedings Volume 4):**

BERLAMONT, van GOETHEM, BERLEUR & van BRUWAENE: "A Permanent Mud Pumping Installation as an Alternative for Local Maintenance Dredging."

BRAHME & BAPAYE: "Studies for the Development of a New Approach Channel."

COEFFE, CHALOIN & PECHON: "Application d'une Modélisation Numérique des Courants de Marée et du Transport Solide." ("Applications of Numerical Simulation of Tidal Currents and Sediment Transport.")

JOHNSTON, ELSAWY, HAMILL & MCKILLEN: "A Study of Scour and Deposition Near a Berth Structure Caused by Propulsion Action of Manoeuvring Ships."

LENN & ENEVER: "The Measurement of the Size and Concentration of Suspended Fine Sands Using Scattered Ultrasound."

MARKOFSKY, LANG & SCHUBERT: "Suspended Sediment Transport in Tidal Waters: Turbidity Maximum, Numerical Simulation, Physical Aspects."

RIEDEL: "Tailings Disposal – Empress Augusta Bay, Bougainville."

van RIJN & NIENHUIS: "In-Situ Determination of Fall Velocity of Suspended Sediment."

**Seminar (c) Case studies in hydraulic transients**  
Location: Seminar Room  
Seminar Organizer: Mr. E. J. Lesleighter, Snowy Mountains Engineering Corporation  
Lead Papers (Proceedings Volume 6):  
H. BREKKE: "Analysis of Pressure Surges."  
M.H. CHAUDRY: "Aspects of Hydraulic Transients."  
Other papers by various authors available at door.  
Simultaneous translation not provided.  
**FLOMEKO '85 Session – 1350-1540 Thursday 22nd August 1985**  
**Cross-Correlation and Constrictions**  
Location: Theatre A  
Chairman: Dr. H.H. Dijstelbergen  
Co-chairman: Mr. S. Morgan  
Presentation by Authors  
Simultaneous translation not provided  
Papers:  
BATTYE: "The Industrial Correlation Flowmeter and Its Design Constraints."  
KEECH & COULTHARD: "Advances in Cross-Correlation Flow Measurement and its Application."  
KICHEV, THOM & FOORD: "Devices with Measuring Constrictions Elastically Supported."  
SHAO CHANGCHUN: "Measurement of Wet Steam Flow."

1530-1600 Afternoon Tea

1600-1730 **Technical Session 12**

Technical Session 12B – 1600-1730 Thursday 22nd August 1985

Sub-theme B.(f) – Rainfall and runoff models

Location: Theatre B

Chairman: Assoc. Prof. R.G. Mein, Monash University

Session Organizer: Dr. A.H. Wong, Gutteridge Haskins & Davey

Presentation by Authors

Simultaneous translation not provided

Papers (Proceedings Volume 3):

HAGER: "A Non-Linear Rainfall-Runoff Model".

WILLIAMS & FIELD: "Real Time Flood-Forecasting Using Non-Linear Conceptual Rainfall-Runoff Models".

HARBOE: "Models for the Security in Areas Protected Against Flood Flows Through Reservoirs."

TSYKIN: "Extrapolation of Rainfall-Runoff Regression Models Outside Their Calibration Range".

BERGMANN & SACKL: "Two Dimensional Frequency Analysis of Flood Water Flow and Its Application in Water Management."

Technical Session 12C – 1600-1730 Thursday 22nd August 1985

Sub-theme C.(a) – Currents in coastal areas and estuaries

Location: Public Lecture Theatre

Chairman: Mr. T.L. Walton, Jr., U.S. Dept. of the Army

Session Organizer: Mr. D. L. Reid, Monash University

Presentation by Authors

Simultaneous translation provided

**Papers (Proceedings Volume 4):**

- BONNETON & GAILLARD: "Numerical Calculation of Wave-induced Currents."  
LEE, LI & CHOI: "Simulation of Tidal Circulation in a Coastal Bay: A Comparative Case Study."  
LE HIR & SALOMON: "A Study of Residual Circulation in the Bay of Seine."  
van SENDEN: "Structure of Tidal Jets Under Variable Source Conditions."  
FUKUOKA, FUKUSHIMA & TSUNODA: "Fresh Water Flow in a River Mouth."

**Seminar (c) Case studies in hydraulic transients (continued)**

Location: Seminar Room

FLOMEKO '85 Session - 1600-1730 Thursday 22nd August 1985

**Pulsating Flow**

Location: Theatre A

Chairman: Dr. E. A. Spencer, O.B.E.

Co-chairman: Dr. H.H. Dijstelbergen

Presentation by authors

Simultaneous translation not provided

**Papers:**

- MOTTRAM: "Measurement of Noisy and Pulsating Flows in Industrial and Laboratory Environments."  
HEBRARD, BISCOS, GAJAN & PLATET: "An Investigation of the Behaviour of Orifice Meters in Pulsating Flow Conditions."  
FOSS: "The Calibration of Viscous Flowmeters Subject to Pulsating Flow."

1900 for

1930

Congress Banquet

**FRIDAY 23 AUGUST 1985**

0830-0900 Registration - Logic Classroom, Old Arts Building

0900-1030 **Technical Session 13**

Technical Session 13B - 0900-1030 Friday 23rd August 1985

Sub-theme B.(d) - Sediment transport in rivers

Location: Theatre B

Chairman: Prof. A. Raudkivi, University of Auckland

Session Organizer: Mr. W.T. Wong, Monash University

Presentation by General Reporter, Prof. K. RANGA RAJU, University of Roorkee

Simultaneous translation not provided

**Papers (Proceedings Volume 3):**

- ARMANINI & DI SILVIO: "Transport of Suspended Sediments Along Channels with a Trench."  
CELIK & RODI: "Mathematical Modelling of Suspended Sediment Transport in Open Channels."  
GRAF & SUSZKA: "Unsteady Flow and its Effect on Sediment Transport."  
HSU & HOLLY: "Numerical Computation of Alluvial River Bend Flow and Equilibrium Geometry."  
KARIM & KENNEDY: "Kinematic Analysis of Characteristic Time Scales for Bed Degradation and Aggradation in Alluvial Streams with Nonuniform Sediment."

LU & SHEN: "Evaluation of H. A. Einsteins Hiding Factor for Transport Non-uniform Sediment Sizes."  
MUKHAMEDOV, JURAEV & ISHANOV: "Investigation of Basic Parameters in Sand Canals."  
PHILLIPS & SUTHERLAND: "Numerical Modelling of Spatial and Temporal Lag Effects in Bedload Sediment Transport."  
SINGH & SCARLATOS: "Sediment Transport in Vertically 2-D Man-Made Canals."  
THOMAS & SUTCLIFFE: "Some Hydraulic Aspects of Sewage Settlement Tanks."  
WESTRICH & JURASCHEK: "Flow Transport Capacity for Suspended Sediment."

Seminar (d) Small hydropower generation

Location: Public Lecture Theatre

Seminar Organizer: Prof. J.L. Woodward, University of Auckland

Lead Papers (Proceedings Volume 6)

D.R. PRESTON: "River Intakes"

J.N. DUDEK: "Structures: Construction Material and Techniques and Maintenance"

B.W. LEYLAND: "Mechanical and Electrical Aspects"

Other papers by various authors available at door.

Simultaneous translation provided.

1030-1100 Morning Tea

1100-1230 Technical Session 14

Technical Session 14B - 1100-1230 Friday 23rd August 1985

Sub-theme B.(e) - Hydraulic Structures

Location: Theatre B

Chairman: Mr. P. Ackers, Binnie and Partners

Session Organizer: Mr. W.T. Wong, Monash University

Presentation by Authors

Simultaneous translation not provided

Papers (Proceedings Volume 3):

GIESECKE & HORLACHER: "Automatically Operating Flexible Weirs in Small Hydro Stations and in Agricultural Irrigation Systems."

OGIHARA & MURAMATSU: "Causes of Oscillation in Rubber Dams and Countermeasures".

DUGGINS & EGGLER: "A Flow Modulator for Hydraulic Applications."

PILARCZYK, KOLKMAN & UWLAND: "Prototype Measurements on Discharge Sluices in the Netherlands."

Seminar (d) Small hydropower generation (continued)

Location: Public Lecture Theatre

Poster Paper Session (Authors present)

Location: Corridors, Old Arts Building

1230-1400 Lunch

1400-1530 Technical Session 15

Technical Session 15B - 1400-1530 Friday 23rd August 1985

Sub-theme B.(e) - Hydraulic Structures

Location: Public Lecture Theatre

Chairman: Mr. P. Ackers, Binnie and Partners

**Session Organizer: Mr. W.T. Wong, Monash University**

**Presentation by Authors**

**Simultaneous translation provided**

**Papers (Proceedings Volume 3):**

OGIHARA: "Unstable Condition of Self-excited Oscillation of Flap Gate".

MICHELS: "Rosslynne Spillway: Mitre-Prowed Overfall Weir with Sharply Convergent Walls & Skew-Impacted Trough Apron".

LOPARDO & HENNING: "Experimental Advances on Pressure Fluctuations Beneath Hydraulic Jumps."

BANDLER: "Water Supply to Bandung and Yogyakarta, Indonesia – Environmental Implications and Sanitation Measures."

**Technical Session 15C – 1400-1530 Friday 23rd August 1985**

**Sub-Theme C.(d) – Environmental aspects of estuaries and coastal areas**

**Location: Theatre B**

**Chairman: Dr. I.G. Wallis, Consulting Environmental Engineers**

**Co-chairman: Dr. N. Haritos, University of Melbourne**

**Session Organizer: Mr. D. L. Reid, Monash University**

**Presentation by Authors**

**Simultaneous translation not provided**

**Papers (Proceedings Volume 4):**

BLOSS, WOLLRATH & ZIELKE: "Optimal Control of Discharges Into Unsteady Flows."

MAROTZ: "Head Losses in Intake Pipes of Desalination and Powerplants, Caused by Mussel Incrustation and Methods of Prevention."

ONISHI & MIYAZAKI: "Theoretical and Experimental Study of Submerged Multiport Diffuser."

UDA & HASHIMOTO: "Field Investigation of Nearshore Circulation by a Remote Sensing Technique."

VAIDYARAMAN & PUTTARAMAIAH: "Discharge of Sediment Laden Water into the Open Sea."

**1530-1600 Afternoon Tea**

**1600-1800 Plenary Session**

**Location: Wilson Hall**

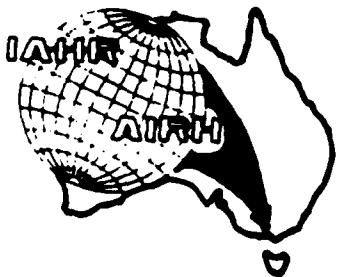
**1600-1620 Address by Prof. J.S. McNow, Royal Institute of Technology, Sweden: "Hydraulics on Display."**

**1625-1725 General Assembly of the International Association for Hydraulic Research**

**1730-1800 Closing Ceremony of 21st Congress**

**1800-1900 Farewell Party**

**Location: Wilson Hall**



International Association for Hydraulic Research

Twenty First Congress

Opening Ceremony

in

The Wilson Hall

The University of Melbourne

Monday, 19th August, 1985.

in the presence of their Excellencies

The Administrator of the Commonwealth of Australia

Sir James Rowland K.B.E. and Lady Rowland

- Order of Proceedings -

- . Musical interlude
- . Official Party enters Hall
- . National Anthem
- . President of I.A.H.R., Prof. Dr.-Ing. E.J. Plate.
- . Chairman of I.A.H.R. Local Organizing Committee,  
Prof. J.D. Lawson.
- . Chancellor of The University of Melbourne,  
Prof. Emeritus Sir Douglas Wright A.K.
- . Prof. Dr.-Ing. Plate
- . His Excellency, The Administrator of the Commonwealth  
of Australia, Sir James Rowland K.B.E., D.F.C., A.F.C.
- . Prof. Dr.-Ing. Plate
- . I.A.H.R. Keynote Speaker, Prof. Dr.-Ing. G. Garbrecht.
- . Prof. Dr.-Ing. Plate
- . Official Party leaves Hall
- . Refreshments

Music: University Organist,  
Mrs. Constance Calwell.  
Bach and Handel  
(celebrating 300th  
anniversary).



RURAL WATER COMMISSION  
HYDRAULIC EXPERIMENTAL STATION, WERRIBEE

MODELLING WITH WATER

The hydraulic model has been recognised for nearly a century as an essential tool in the design and operation of both large and small hydraulic structures such as dams, spillways, pipelines and channels. Most large water authorities throughout the world have established hydraulic laboratories in which models of water engineering works are constructed and tested.

Model tests permit solution or clarification of many problems which are difficult or insoluble by normal analysis or design methods.

In the great majority of cases, the tests ensure not only safety in operation and economy but also effect substantial financial savings, far outweighing the cost of the experimental work involved.

There are two main types of hydraulic laboratories - Research and Experimental. Pure-research oriented laboratories are concerned with the study of the fundamentals of hydraulics, and are generally attached to universities and colleges of technology and specialised manufacturing organisations. The results of these studies are incorporated in state-of-the-art design techniques.

Hydraulic experimental laboratories are usually incorporated in large government agencies responsible for the operation and management of water supply or navigation undertakings. They are aimed chiefly at aiding the design of hydraulic structures, employing tests or trials for checking or verifying the success of a particular hypothesis for given or different conditions, using a definite procedure.

The Werribee Hydraulic Experimental Station established by the State Rivers and Water Supply Commission, (SRWSC), predecessor of the Rural Water Commission, is of this type, and is an integral part of its Design Division.

HISTORY OF STATION

During the design of Yarrawonga Weir on the River Murray in the 1930's, Commission engineers realized that hydraulic model studies would be required. A small model was tested at Melbourne University, and then a larger model in the Commission's Bacchus Marsh District.

In 1947, the enlargement of Eildon and construction of Cairn Curran dams was being planned as part of a program for expansion of water supply in Victoria, the SRWSC decided to establish a hydraulic model testing station as an essential adjunct to the design procedure. Construction commenced in 1949 and the Station was operational in 1950.

Werribee, which is conveniently close to Melbourne, was chosen as the site because land was available adjacent to the existing Commission District Office, with a superseded town water supply concrete settling tank and high level water tower to provide a basis for a recirculating system of water supply.

The Hydraulic Experimental Station has served the State water industry well since then, testing 240 models of all types with benefits to more effective operation and cost savings for water supply systems.

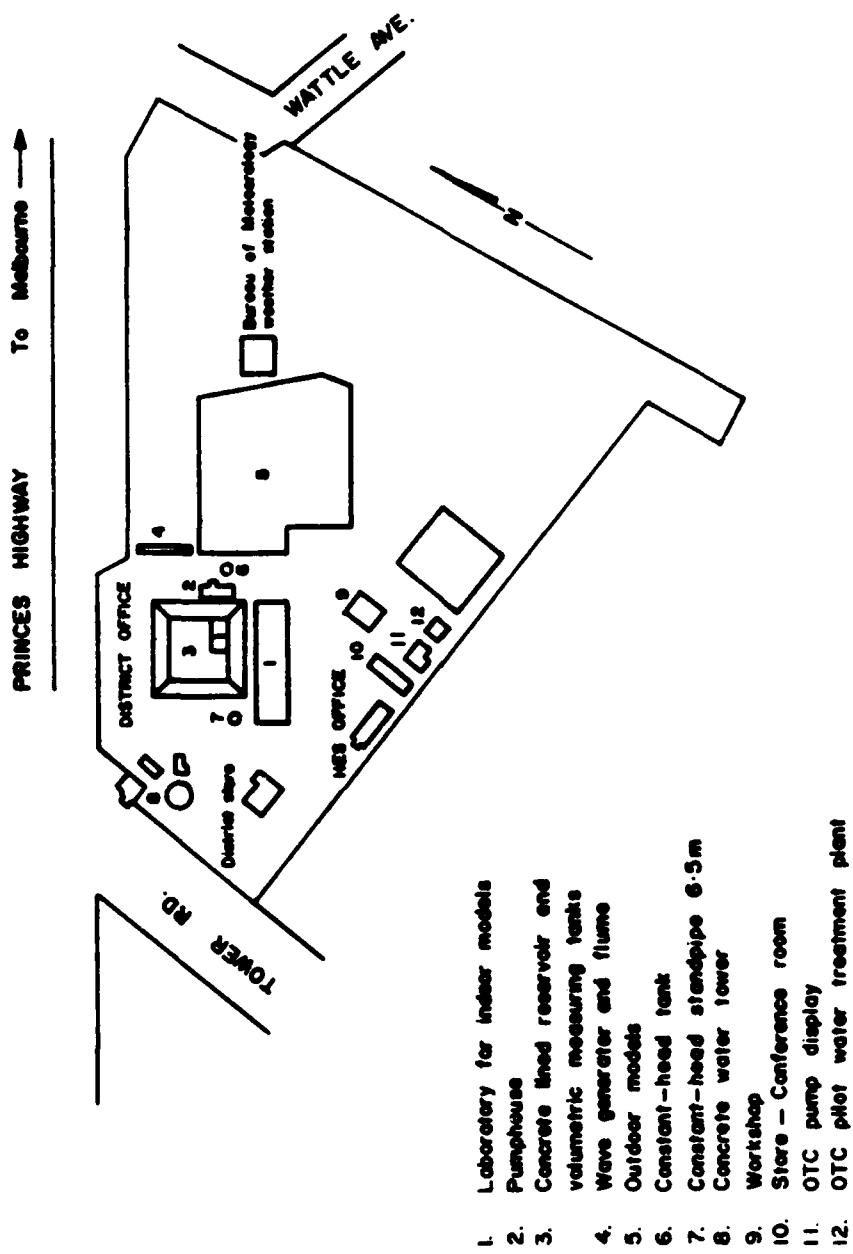
#### STATION FACILITIES

The Station water supply system can provide flow rates up to 300 L/S (26 ML/d) and has National Association of Testing Authorities registration for the calibration of flow measuring devices to an accuracy of  $\pm 0.75\%$  using volumetric measuring tanks. A large laboratory and extensive outdoor area, both with constant head supply tanks, provide excellent facilities for carrying out large scale model tests relevant to the water industry.

The Station has conducted investigations and model testing in the following fields:

- . improvements to and checking of designs of irrigation and drainage channel structures, including reduction of erosion and improving energy dissipation, calibration of measuring weirs, siphons, offtakes, regulating gates, and pipe flow meters. Results from these tests have contributed to the development of standard structures for irrigation and drainage works.
- . improvements to and checking of design of components such as spillways, outlet works, and energy dissipators for dams.
- . determination of flow characteristics and discharge coefficients of spillway crests of various shapes operating under free-flow or gate-controlled conditions.
- . calibration of propeller and other flow meters for pipe sizes up to 375 mm.
- . river model studies for flood prevention, diversion, drainage and control, and studies in siltation and scour prevention.

The Station is available to carry out studies for other authorities and private organisations. Enquiries should be directed to the Resident Engineer (03 741-2999) or the Commission's Chief Designing Engineer, Major Projects Design Division, 590 Orrong Road, Armadale 3143, Victoria.



Prepared by Design Draughting  
July 1985

# BENMORE

Waitaki Valley  
North Otago



## CONTENTS

EARTH      DAM      CONSTRUCTION      STATISTICS

RIVER      DIVERSION      LAKE      FILLING

INTAKES      PENSTOCK      SPILLWAY

DIMENSIONS      FACTS AND FIGURES

ELECTRICAL      D.C. TRANSMISSION SYSTEM

UPPER WAITAKI AND MACKENZIE COUNTRY HYDRO-ELECTRIC DEVELOPMENT

# BENMORE

## DIMENSIONS

One half a mile long across the top, one quarter of a mile thick at the base, 360 feet high.

It took five years to place the sixteen million yards (twenty seven million tons) of material in the dam.

The Lake behind the dam extends 22 miles up the Waitaki valley towards Mt Cook and a further 12 miles up the Ahuriri valley towards Omarama, contains 17 islands, has 32 square miles of surface area and has nearly 100 miles of shoreline. The lake took six weeks to fill instead of the predicted six months and as predicted the dam has moved 2 inches under the weight of the water.

The Spillway has been designed to take twelve times the flow of the river.

The dam, spillway and powerhouse cost sixty million dollars some twelve million dollars LESS than estimated while the direct current powerline to the North Island including the three underwater cables across Cook Strait a further thirty-six million dollars.

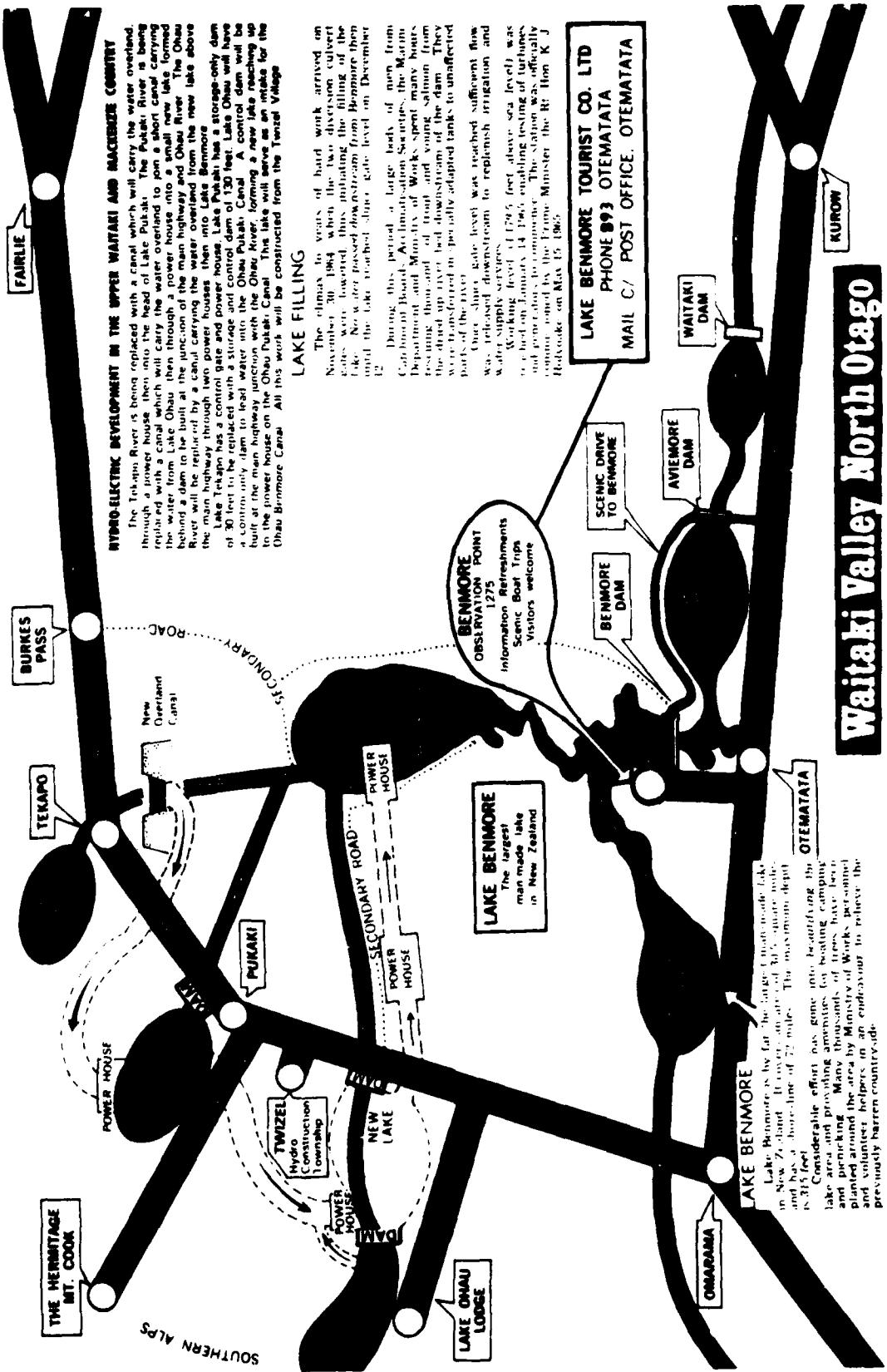
The project was officially opened in May 1965 by the Prime Minister Keith Holyoake and guest of honour at the occasion was Prince Bertil of Sweden whose Country supplied much of the direct current electrical equipment

All Benmore power is generated as alternating current but North Island requirements are converted to direct current, transmitted up to and under the sea at Cook Strait and on out to the North Island where it is reconverted back to alternating current to be fed into the National Grid.

This system gives a loss of only nine percent as against a possible forty percent loss with alternating current which in effect is not suitable for transmitting underwater.

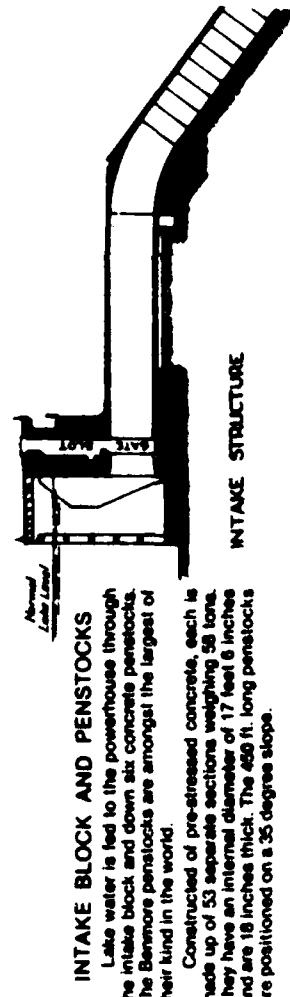
The conversion system is Mercury Arc Rectifiers.

# BENMORE

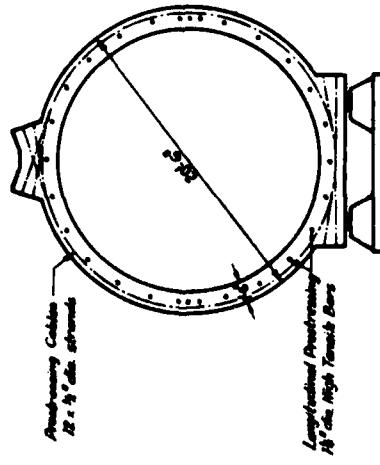


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Bennmore's main features are the huge earth dam; the intake block, penstocks and powerhouse situated on the Ohau side; and the spillway structure at the Canterbury side of the dam.



#### INTAKE STRUCTURE



Cross-section of a pre-stressed concrete penstock showing the longitudinal and circumferential anchoring tendons. The six penstocks, each 400 ft. long, are cast in 5 ft. sections. Each section weighs 58 tons. The internal diameter is 17 ft. 6 in. Some 216 sections are needed to complete the six penstocks.

#### D.C. TRANSMISSION SYSTEM

Two 220,000 volt lines lead off from the outdoor A.C. station to link Bennmore with the South Island network. One runs 180 miles north to Wellington substation, the other 55 miles south to Livingstone. The line south will later become two lines to Aviemore power station.

At the foot of the penstock slopes are the powerhouse buildings. Down stream of them, on the right bank of the river, is the converter station which charges alternating current at 110,000 volts into direct current at 500,000 volts for transmission to the North Island via the 370-mile inter-island link. On the left bank is the outdoor alternating current station through which power is supplied to the South Island transmission network. This dual character - the capacity to supply the north through a direct current system and the south through an alternating current one - makes Bennmore unique among New Zealand power stations. By increasing the allocated generation to either island as desired, hydraulic conditions throughout New Zealand can be balanced. The basic process of conversion from alternating to direct current is performed by the 24 mercury arc valves. Electrical current passes from the anode, the top of the valve, down via four cylindrical tubes and the mercury vapour to the cathode, the base of the valve. The valves effectively stop and start the flow of the current passing through them at a very rapid rate and thus transform the normal pulsating current into steady flowing direct current.

The valves and control equipment are located in a fully air conditioned valve-house which is completely shielded by a steel mesh inside the walls to reduce radio interference. There is also much outdoor equipment of a special nature, the most impressive items being two smoothing reactors which are used to reduce the ripple in the D.C. voltage. These weigh 80 tons each and for technical reasons stand on four 8-foot-high porcelain insulators.

About 3 miles from the power station, but closely associated with the converter equipment, is the Bennmore land electrode where current passing through the earth from the North Island is collected for return to the converter equipment. The design of this electrode was a major undertaking because no information was available on any comparable electrode. It extends over an area of 800 x 700 yards and consists of 2,300 yards of heavy steel rod and 350 tons of coke buried in six radial trenches. Total capacity of the converter station and D.C. transmission link is 600 megawatts. This is 60 megawatts more than that of Bennmore generating station, but power generated elsewhere in the South Island can be fed into the link via the Bennmore converter station to make up the 600 megawatts if required.

At present the installation is the most powerful of its kind in operation with the exception of one in the U.S.S.R. The D.C. link is the longest in the world by a substantial margin.

For the average visitor, however, Bennmore's chief attraction lies in its vast dam and in the magnificent lake which has been created in former barren hill-country. It is already a tourist attraction and its beauty will increase as the thousands of trees now being planted about it grow to maturity.

## POWERHOUSE

Two 220,000 volt lines lead off from the outdoor A.C. station to link Benmore with the South Island network. One runs 160 miles north to Livingston substation, the other 35 miles south to Livingstone. The line south will have four more two-liners to Avenue power station.

The basic process of conversion from alternating to direct current is performed by the 26 mercury arc valves. Electrical current passes from the anode, the top of the valve, down via four cylindrical tubes and the mercury vapour to the cathode, the base of the valve. The valves alternately stop and start the flow of the current passing through them at a very rapid rate and thus transform the normal pulsating current into steadily flowing direct current.

The valves and control equipment are housed in a fully air conditioned valve-house which is completely shielded by a steel mesh inside the walls to reduce radio interference. There is also much outdoor equipment of a special nature, the most imperative items being two smoothing reactors which are used to reduce the ripple in the D.C. voltage. These weigh 160 tons each and for technical reasons stand on four 8-foot-high porcelain insulators.

About 3 miles from the power station, but closely associated with the converter equipment, is the Benmore land electrode where current passing through the earth from the North Island is collected for return to the converter equipment. The design of this electrode was a major undertaking because no information was available on any comparable electrode. It extends over an area of 6000 x 700 yards and consists of 2300 yards of heavy steel rod and 350 tons of coke buried in six radial trinities.

Total capacity of the converter station and D.C. transmission link is 600 megawatts. This is 60 megawatts more than that of Benmore generating station, but power generated elsewhere in the South Island can be fed into the link via the Benmore converter station to make up the 600 megawatts if required.

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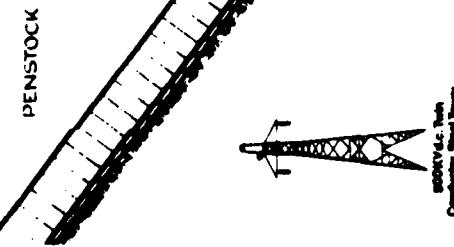
## ELECTRICAL

**Energy (Kwh)** [kilowatt-hour] is the work which electric power does in a given period, and is power multiplied by time. A kilowatt-hour is known commercially as "a unit". Your power bill is charged according to the number of units used. A one-horse electric heater, for instance, will use one kilowatt in one hour, i.e., it will use one "unit".

## SPILLWAY AND SLUICE STRUCTURE

Periodically, into the lake behind the dam, there will be a flow of water too great for power generating purposes. In this eventuality, the spillway structure will act as a "safety valve" passing excess water downstream via its 1,350 feet long channel. The spillway sluices enable the lake to be lowered if required for maintenance purposes.

Before major construction work can commence in earnest on a hydro-electric scheme the course of the river must be controlled so that work can be carried out in dry conditions. To effect this at Benmore a twin-tunneled culvert was constructed, each tunnel being 41 feet high, 25 feet wide and 1,400 feet long. The culvert was designed to carry six times the normal river flow which was the maximum flow likely to occur during the critical construction period. The river was successfully diverted to flow through the culvert in August 1950.



## THE POWERHOUSE

The powerhouse, situated at the bottom of the penstock slope, houses six 125,000 h.p. turbines which are each connected to a 90,000 KW generator. Two auxiliary machines each generate 3,000 KW of power for various local purposes.

The main powerhouse structure is 400 feet long, 140 feet high from excavation to roof top and is constructed of reinforced concrete. Adjacent to the main building are a workshop, office block and control block.

## POWERHOUSE

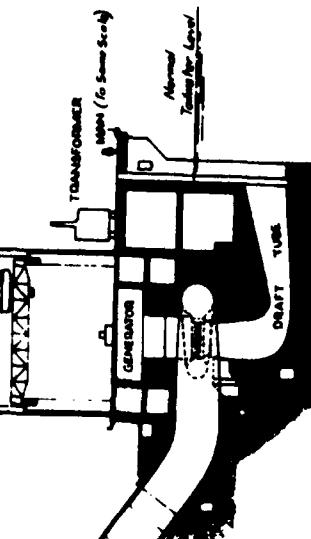


Diagram showing the power unit — Intake, penstock and powerhouse. The intake is set in a concrete gravity dam. Down the penstock enters to the powerhouse. After leaving the intake, the penstocks drop 271 ft. down a 26-degree slope to the powerhouse where the six generators will have a capacity of 540,000 kilowatts.

WAITAKI HYDRO-HISTORY

All authorities claim that the earliest inhabitants of the Waikati Valley were a native race. No specific people are known to us today as the Maia hunters. Evidence of their dwelling in this area has been discovered in numerous ancient ruins that can be seen within the last 20 years or so, and consists chiefly of primitive designs painted on the walls of rock shelters, which are to be found at various sites in the valley. In time other tribes in the form of warring parties came to the valley, and with them they brought their customs, religions, and beliefs. The Maia hunters have been instrumental in giving weight to the theory that in some way they were the original inhabitants of the area and this name seems to have been applied to all native dwellers who arrived here during the first half of the nineteenth century.

The year 1868 saw the invasion of the South Island by the Ngati-namoe and some 100 years later, the Ngati-tahu. These two peoples, in spite of long periods of warfare, exploration and some inter-marrying, were never enemies and both used sheltering places in their inter-tribal campaigns.

Waikati River, cinnabar today with its various power stations, so did long before the white man though in a more indirect manner. For it was along the banks of this river that the Maia tribes often travelled on the way to the West Coast to hunt seals and to fish for salmon.

No history in the Waikato Valley, no matter how brief, can be told without making some mention of him. Walter B. D. Mantell, for it was he who was responsible for the early exploration and descriptions of the area as the first European to penetrate into the Upper Waikato country.

Mantell undertook this expedition in 1848 as part of his office as commissioner appointed to settle native affairs in the South Island. Following a route map drawn by his native guide Te Ware Korari Mantell explored the countryside at least as far as present-day Ohurama and possibly further. He reached Ohurama in December, 1852, the year in which it is said that expeditions under Maori guides seemed to cease. At about the same time a few native villages were still to be found in the valley, but the majority of the Maoris had shifted to Meremere.

From 1853 isolated homesteads began to appear in the valley and heralded the era of the runholder. Demata (Andrews), Te Akatarawa (Edmund Gibson) and Haldon (Frederick and Thomas Crean) all came into prominence in the year 1857 and still dominate the agricultural scene under their present holding families—the Cartmores, Whiskins and Innes. But there is another story.

SPILLWAY, INTAKES, PENSTOCKS

The behaviour of the dam under working conditions is checked by reading ranges in three instrument-houses, two located on the downstream face and one in the right concrete abutment. These ranges are attached by long plastic tubes to piezometers (instruments for measuring water pressure between the core particles) and hydrometric settlement gauges, placed inside the dam during construction.

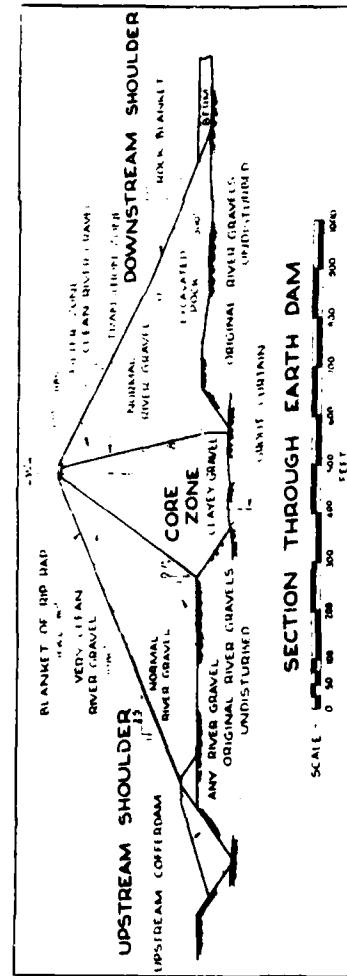
The dam fields back New Zealand's largest man-made lake which covers 10 square miles and contains one-and-a-half times as much water as the Wellington harbour. Under operating conditions water level can be controlled over a range of up to 20 feet, though in practice fluctuations are much smaller. Normal retention level is 10 to 12 feet below the dam crest, i.e. 1,130 to 1,140 feet above sea level. Under very unusual circumstances, for example, if it became necessary to demolish the intake structure in order to repair it the lake could be drawn down to 1,100 feet above sea level by means of the sluice gates located to the left of the dam looking downstream.

The 124-foot-high concrete spillway structure, besides the two sluices in its base, has four radial steel gates at retention level. Maximum rate of discharge through the gates is 120,000 cubic feet per second, which is the greatest flood likely to occur in a 1,000 year period, or 10 times the normal rate of outflow. In due course a further 60,000 cubic Water Passes through the spillway runs down a sloping channel to a deflector

At the opposite end of the dam are the intake block and 271-foot-high pressurized pipe. The former consists of massive concrete blocks, containing six bellmouth entries which lead into the six main penstocks. The entries are each regulated by 16-ton gates, and are protected from floating debris by screens placed between the pens of a bridge immediately upstream of the intake structure. Because of their bulk and the need to maintain a very high quality of concrete, the main sections of the penstocks were not built in situ. Three hundred and eighteen prestressed concrete units, each 12 feet long, 173 feet inside diameter and weighing about 56 tons were built in a casting yard about a mile away, transported individually to the top of the slope, and winched down into position, each unit being placed 1½ inches above the preceding one and joined to it by coupling the longitudinal prestressed bars and pumping fluid mineral into the vacant space. Short sections near the intake and leading into the penstocks were built in situ of reinforced concrete with a steel liner.

The penstock structure measures 60 feet from intake mouth to intake valve casings, and conveys water from the lake to the turbines at a rated head of 302 feet.

**Voltage (V)** is the pressure of electricity and is measured in volts. It is the flow of electricity and is measured in ampere (amp). Current (in amp) multiplied by voltage (in volt) approximately equals power (in watts). In other words, power = voltage  $\times$  current.



## CONSTRUCTION RIVER DIVERSION

Bennmore is the third and largest of a series of stations to be built in the Waitaki River Basin. It stands just below the confluence of the Waitaki and Ahuriri rivers, a site chosen for investigation in 1946, as being particularly suitable for a large earth dam. Prior to this, several sites had been spent investigating a site 3 miles upstream where the Waitaki passes through a narrow gorge known as Black Jack's Point, which seemed suitable for a concrete dam flat with the development of large earth-moving equipment in the relative ease of earth dams demanded and the more open site downstream became the more attractive alternative. Government approved diversion in 1957 and in 1958 work began on the river diversion scheme.

The 1.4 mile long diversion cut-off, now inside the dam, was built in a later trench excavated on the left bank of the river. It consisted of two arched stone arches 40 feet wide and capable of carrying almost four times the normal river flow. The river was diverted into them in August 1960. Four years later, when the time came for lake filling, they were closed by lowering two 153-ton steel gates from concrete towers built over the cut-off near its upstream end, and the partial backfilling with gravel. Later rock-fill and concrete piles were added to make a permanent water seal.

The dam spans the valley between two natural prominences, one accommodating the spillway, the other the intake block and intakes. Its construction was the largest job of its kind ever undertaken in New Zealand and involved cutting and compacting 20 million tons of material. The core consists of a barrier of impervious clays, gravel resting on a graded rock surface. Supporting the core are two massive shoulders of river gravel, with an outer layer of rock riprap as protection against wave action and the elements. The upstream shoulder has a more porous graded gravel in the top 120 feet to accelerate drainage when the lake is being lowered, while at the bottom it incorporates a outlet drain to aid diversion.

The Bennmore Dam is one of the largest earth dams in the world and holds back the largest man-made lake in New Zealand. Bennmore is the largest D.C. transmission station in the world.

## STATISTICS

Maximum structural height, 360 ft	Capacity 600,000 KW
Width at base, 1,600 ft	Max. Operating Voltage, 540,000 Volts
Width at crest, 35 ft	Efficiency, Overall Average, 90%
Length at crest, 700 ft	Number of Valves, 28
Overall length, 7/8 mile	Voltage per Valve, 120,000 Volts
Volume, 16 million cubic yards	Current per Valve, 1,200 Amperes
Four spillway gates each 67 tons	Length of Line, 355 miles
Two sluice gates each 54 tons	Length of Cable, 25 Miles
Average water flow in river, 12,000 cusecs	Number of Towers, 1,646

## FACTS AND FIGURES

Considerable effort is lent by the Ministry of Works towards ensuring that the dam and lake areas of new hydro-electric schemes add to the attraction of the countryside. Dams are designed to blend in as well as possible with the adjacent area, and boatharbours, camping grounds and picnic areas are established at suitable locations around the lake-sides.

Trees offer one of the best means of improving the scenery and many thousands are planted each season with this in mind. In 1965/66 season alone, more than 80,000 trees were planted about the Benmore-Aviemore area. A good survival rate has been achieved so future generations will benefit greatly from the effort applied in this direction now.

## BACKGROUND

New Zealanders use electricity freely their rate of domestic consumption being amongst the highest in the world. A growing population and increasing industrialisation necessitated the generation of progressively greater quantities of electricity at an economical cost.

Despite the high initial capital costs of constructing the stations, hydro electric power is cheaper than that from thermal stations due to the fact that no fueling costs are involved.

In the light of this, it is evident that the Waitaki Hydro Electric developments will play a rôle second to none in helping to fulfil the power requirements of the nation for many years to come.

The ultimate potential of the river is

estimated in excess of 2,000,000 kilowatts

indicated a large contribution to the national consumer demand.

A further important aspect of the Waitaki project is that Benmore is the largest of the river's dams and power stations is also the southern terminal of an inter island transmission system through which power generated in the South Island can be fed to the North Island where the greatest demand exists.

Power (W) is the rate at which electrical energy is produced or consumed. Power is measured in watts, or more conveniently in kilowatts (thousand of watts), megawatts (millions of watts or thousand of kilowatts) or even in gigawatts (millions of kilowatts).

## REGENERATION

Proposals for developing water power schemes on the Waitaki River were included in comprehensive reports on all sources of water power then known in the Dominion, which were submitted to Government by an American consulting engineer and the Superintending Engineer for the then Public Works Department in 1904.

Both recognised the high potential of the river basin and reported it in glowing terms, but they were practical men and had to take into account the immediate needs of the community of those days as well as the nation's limited ability to finance and construct large works. They had to reject schemes which by present day standards would be ideal. No one man could put together the numerous ill-sawed parts of a hydroelectric scheme.

Engineering design and the solutions to

problems brought to light by investigations are worked out by teams of engineers in projects, draughtsmen and technicians skilled in hydraulics, concrete technology, structural analysis, soil mechanics, building construction and the use of mechanical equipment. This work results in drawings, specifications and other technical instructions.

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### Machinery and Access:

Benmore's earthmoving and mechanical equipment is impressive even by world standards. Ministry of Works and contracting plant used on the earth dam is set out in the following table:—

#### BULLDOZERS:

Machine	Number on Project
Caterpillar D8s	31
Caterpillar D9s	6
Caterpillar D7s	1
Caterpillar D4s	2
International TD25s	2
Euclid TC12s	3
Euclid C6s	2

#### RUBBER-TYRED SCRAPERS.

International 495s	15
Caterpillar 631s	4
Caterpillar DW21s	10
Euclid TS24s	3
Euclid S18	1

#### EXCAVATORS:

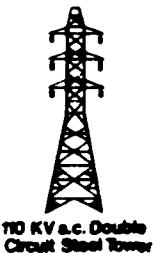
Marion 111M 4yd.	4
Osgood 2½yd.	2
Marion 40A 2½yd.	1
NCK ¾yd.	2
Caterpillar 944 Front-End Loader. 2¼yd.	2
Allis Chalmers 6G F.E.L., 1½yd.	1

#### DUMP WAGONS:

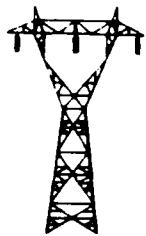
Haulpak 27	10
Euclid 49FD and 82FD	11
Euclid B3FD	9
Euclid B1TD	8

#### MISCELLANEOUS:

Airtrac Drills	8
50-ton rubber-tyred rollers	4
Vibrating rollers	9
Graders	6



110 KV a.c. Double Circuit Steel Tower



220 KV a.c. Steel Tower



220 KV a.c. Double Circuit Twin Conductor Steel Tower

## FISH PROTECTION

For a week after the river was sealed off at Benmore to effect the filling of the lake, up to 100 men were occupied rescuing thousands of fry and small fish from ponds in the river bed downstream.

At Aviemore, an artificial spawning race for trout is to be built below the dam. Large enough to accommodate 3,000 adult trout, the race will enable fish to be reared in natural conditions.

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